TRAPPING OF XENON UPON EVAPORATION-CONDENSATION OF ORGANIC MATTER UNDER UV IRRADIATION : ISOTOPIC FRACTIONATION AND ELECTRON PARAMAGNETIC RESONANCE ANALYSIS

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Introduction: Carbonaceous chondrites contain an important concentration of carbon, up to 3 wt% in the most primitive meteorites. Most of C occurs as macromolecular insoluble organic matter (IOM) obtained by demineralization of bulk meteorite by HF and HCl [1]. The structure of the IOM, poorly characterized, appears to a mixture of presolar components and amorphous carbon [2,3]. Meteoritic noble gases are located in the IOM and mainly hosted by two carbon-rich phases : nanodiamonds and phase Q [1,2]. Phase Q is the enigmatic carrier of P1 noble gases which represent the majority of Ar, Kr and Xe trapped in primitive meteorites [1]. P1 noble gases are present in different classes of primitive meteorites as well as in differentiated meteorites. [4]. They exhibit comparable elemental and isotopic composition that suggest a common process for shaping P1 characteristic. The mechanism leading to the trapping of P1 is poorly understood. Recently, investigation of the IOM by Electron Paramagnetic Resonance (EPR) shed a new light on possible formation processes of IOM [5]. Results have revealed the presence of heterogeneities in the free radicals distributed in micro-regions [5]. In addition, the EPR signals of Orgueil and Murchison present a temperature dependency which can be interpreted as the occurrence of diradicaloid moieties hosted by aromatic structures of 10 to 15 rings [5]. It has been proposed that the EPR characteristics could be generated by interstellar chemistry or by condensation during the evolving solar nebula [5]. Here we report an experiment designed to study the trapping of Xe by sublimation - condensation process of anthracite. We chose anthracite because it presents an aromatic structure close to the one inferred for the IOM of primitive meteorites [6]. This experiment allowed us to probe the influence of irradiation on : (i) the trapping of Xe onto organic matter, (ii) the EPR signal of organic matter synthesized by evaporation-condensation.

Experimental method : The experimental setup has been described by Tissandier *et al.* (2002) [7]. Anthracite was loaded in a crucible surround by a W filament. UV light was located above the crucible. Air-like Xe was introduced in the system at a pressure of about 0.1 mbar and ionized at an energy of 10MeV/nucleus by high frequency discharge. This energy corresponds to the weak fraction of the galactic cosmic rays and is close to the energy observed in the stellar formation regions [8,9]. The crucible was heated at 1200°C for 5 min and cooled down to room temperature immediately. Organic matter condensed on the different glass parts of the apparatus. Two kinds of samples were recovered, corresponding to ionized xenon or neutral xenon (hereafter referenced as NT for ionizing region and NC for neutral region).

Analytical method : Samples were divided in two parts for noble gases and RPE analyses. For the xenon analysis, organic powder was weighted, wrapped in Ta foil and loaded in a double furnace extraction system. This system allows total Xe release as well as stepwise heating release in the range 200°C to 1200°C. Xe was analyzed by static mass spectrometry in CRPG. The EPR measurements were carried out with a Bruker Elexsys 500 spectrometer operating at 9.4 GHz (X-band) and equipped with resonant cavity and a helium cryostat.

Results : The amount of Xe trapped in NT samples is one order of magnitude higher than the one trapped in NC samples. The Xe concentrations are well reproductible, showing the homogeneity of the trapping mechanism. NC samples show the same xenon isotopic composition as the one of starting Xe (Fig. 1). In contrast, NT samples deposed in the ionizing region present an important isotopic fractionation of 1%/uma relative to the starting composition (Fig. 1). Stepwise heating analysis revealed that NT samples present a temperature range of release between 200°C and 1200°C with a maximum release at 600°C. NC samples show a lower maximum temperature release of 400°C with a release range between 200°C and 1000°C. The EPR spectra as a function of temperature allow the spin concentration to be estimated. Both samples present the same trend characterized by a decrease of spin concentration with increasing temperature (Fig. 2). No significant difference was observed between NC and NT samples despite drastic difference in condensation conditions.

Discussion : The isotopic fractionation observed upon ionization is consistent with previous works in

which isotopic fractionation was observed only during experiments involving irradiation [10-12]. This fractionation could be induced by a charge exchange accompanied by an isotopic exchange :

$$mXe + nXe^{+} \square\ mXe^{+} + nXe.$$

Apparently, the organic matter during its condensation is able to realize a selection between neutral and ions Xe with a slight enhancement for trapping ions. The isotopic fractionation reproduces well the one observed for P1 noble gases relative to solar composition [1].

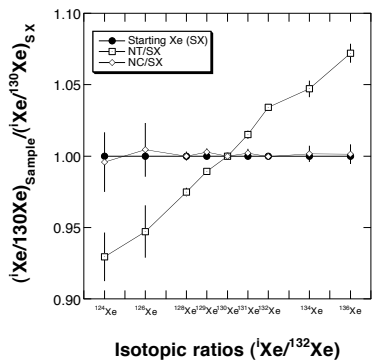

Fig. 1 : Xe isotopic ratio of starting composition and for samples obtained by condensation experiment normalized to starting Xe. NT correspond to the samples recovered from the ionizing region and NC sample from neutral region.

This suggests that Xe-P1 composition could have been generated from a solar reservoir by irradiation, because the energy involved during the present condensation experiment is close to those estimated during stellar formation [9]. It has been proposed than condensation could be at the origin of the EPR signal observed in primitive meteorites [5]. However, the decrease of spins concentration upon temperature determined for both samples is at odds with spins increasing upon temperature obtained for Orgueil and Murchison (Fig. 2 & 3) [5]. The present results suggest that condensation alone does not allow the diradicaloids of IOM to be produced. This observation is in line with [13] who concluded that condensation alone cannot account for the occurrence of nanodiamonds and presolar grains in the insoluble organic matter of carbonaceous chondrites. If condensation is ruled out, interstellar chemistry seems to be the most promising process to reproduce the EPR characteristics. This result supports a presolar origin for P1 noble gases.

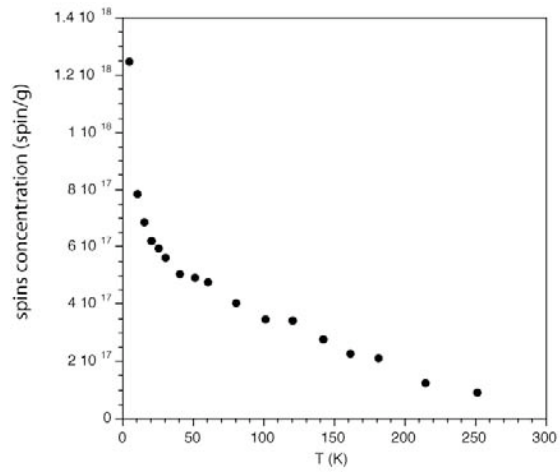

Fig. 2 : Evolution of spins concentration as a function of the temperature of EPR signal measurements for the NT sample. NC sample (not show) presents the same trend. EPR signal of primitive meteorites present the inverse evolution with positive correlation between spins concentrations and temperature.

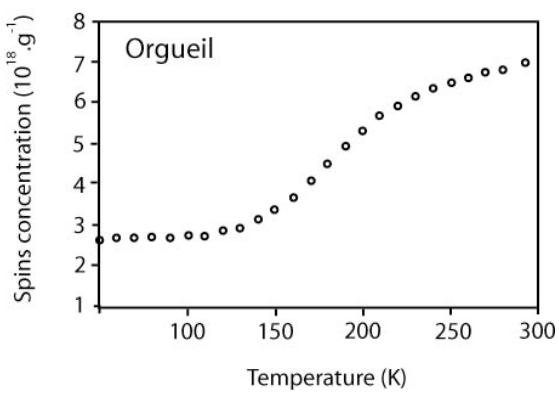

Fig. 3 : Spins concentration upon temperature of the IOM of Orgueil (CI) [5]

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